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Transactions of the 15th International Conference on Structural Mechanics in Reactor Technology (SMiRT-15) Seoul, Korea, August 15-20, 1999

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Integrated Head Assembly for Korean Next Generation Reactor

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ABSTRACT

This paper describes the basic features of the Integrated Head Assembly (IHA) developed by KOPEC for the Korean Next Generation Reactor (KNGR). The previous Reactor Pressure Vessel head area design for the Korean Standard Nuclear Plant (KSNP) consists of many components that needed to be disassembled, stored individually, and reassembled during every refueling outage. In order to reduce the number of steps during the refueling process, beyond those of removing the studs and lifting of the head, the IHA concept has been introduced to the KNGR plant design as shown in the EPRI Utility Requirements Document (URD). The IHA contains not only the RV head, the Control Element Drive Mechanisms (CEDMs), the Heated Junction Thermocouple (HJTC), and the head lift rig as in the KSNP, but also the head area cable tray, the missile shield, the seismic restraints and the CEDM cooling fans and ducts, which can be handled together as a single assembly. It is expected that the IHA concept will contribute to the reduction in radiation exposure to the head area handling operators as well as the reduction in refueling outage duration.

INTRODUCTION

The KNGR project requirement is to design an IHA, in accordance with the concept of the integrated head package in EPRI URD [1], which can be detached from the reactor vessel in significantly fewer steps than for the KSNP. The IHA design will allow the components above the reactor head to be lifted in a single step. The design target is to reduce the number of steps during the refueling process. The general requirement for the IHA design is that the KNGR plant design life of 60 years should also be maintained for the IHA.

The IHA is considered as a mechanical system that can handle the reactor vessel closure head, the Control Element Drive Mechanisms (CEDMs), the Heated Junction Thermocouple (HJTC), the reactor coolant gas vent system (RCGVS) piping, the NSSS Integrity Monitoring System (NIMS) sensors, and the head area cables. The IHA consists of six primary components: Cooling Shroud Assembly, Lifting Frame, CEDM Cooling System including Fans, Missile Shield, Head Area Cable System including Fan Cables, and CEDM Seismic Support. The cable bridge is not structurally connected to any part of the IHA. However, the design of the cable bridge is necessary to provide a connection between the IHA head area cables and the containment cables.

IHA SYSTEM DESCRIPTION

The IHA is a mechanical assembly of various components required to provide cooling of the CEDMs, missile protection for the CEDMs, seismic support for the CEDMs, a lifting system for the reactor vessel head, and the duct work for the air cooling system. All these components are assembled together with the reactor vessel head into a single assembly that can be lifted together in one step and moved to the storage stand as a single structure during refueling (Figure 1). The IHA provides the ability to disconnect the CEDM power cables, the Reed Switch Position Transmitter (RSPT) cables, the RCGVS piping, and other instrumentation lines. The IHA provides an interface between the containment polar crane and the reactor vessel head.

16(c) Cooling Shroud Assembly

The cooling shroud is designed to provide the air flow path to cool the CEDMs that are installed above the RPV closure head during the normal operation of the reactor. The cooling shroud assembly consists of steel columns with an enclosure and a set of baffles to direct the air flow inside the IHA. The cooling shroud is fabricated using carbon steel structural members and steel plates to form an enclosure for the CEDMs above the reactor vessel head. The cooling shroud also provides a cooling air seal in the reactor vessel head region. The supporting columns of the cooling shroud assembly act as load transfer paths between the reactor vessel head and the IHA seismic support restraints. 16(d)

16(a) Lifting Frame

The lifting frame consists of three main column assemblies, a lift tripod, clevises, clevis pins, and a shackle. The lifting frame is designed to meet the requirements of NUREG 0612 [2] and ANSI N14.6 [3]. The lifting frame is an integral part of the IHA and permanently installed on the missile shield, and it is removable from the missile shield, if required. Three main columns are designed as structural members to lift the reactor vessel head during refueling. The main columns function as a load transfer path between the reactor vessel head and the containment polar crane.

16(e) CEDM Cooling System

The cooling system design includes two operating fans and one spare fan to maintain design flow in case of the failure of one operating fan. The cooling system design considers the complete loss of cooling air while holding the Control Element Assembly (CEA) in position for 30 minutes. During this time period, the CEDM shall be capable of being tripped to allow the CEA to drop to the fully inserted position from any withdrawn position. The cooling system design also considers the complete loss of electrical power and air cooling service for a four-hour period with the plant at normal operating temperature and pressure without damage to the CEDM. Each cooling fan is provided with a back draft damper device to prevent backward rotation of a non-operating fan as well as a possible "short circuit" of the cooling system flow path. The design of the cooling fans are based on the amount of heat to be removed from the CEDMs and reactor vessel CEDM nozzles. The cooling fans are anchored to the missile shield platform. The required duct work for the upper air plenum is fabricated using carbon steel sheet metal.

16(f) Missile Shield

The requirement for a missile shield in the IHA is per the NUREG 0800 [4] Section 3.5.2. The function of the missile shield in the IHA is to stop any missiles generated by the failure of the CEDMs. The missile shield also functions as a spreader for the lifting frame, to

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Head Area Cable System

The head area cable system consists of CEDM power cables, RSPT cables, Acoustic Leak Monitoring System (ALMS) / Loose Part Monitoring System (LPMS) cables, HJTC cables, fan power cables and fan instrumentation cables, the cable messenger tray, cable supports on the messenger tray, and refueling disconnect panels (RDPs). The messenger tray is located above the top of the CEDM housings. It provides permanent support and routing for the head area cables. The cables terminate at the refueling disconnect panels which are considered as interfaces with the power cables from the cable tray inside containment. Cable connectors at the refueling disconnect panels are of a quick-disconnect design that can be readily operated by personnel in standard in-containment protective clothing.

X CEDM Seismic Support

The function of the CEDM seismic support is to restrain each CEDM from having excessive deformation at the top of the CEDM in the horizontal direction during an earthquake event. The CEDM seismic support will transfer seismic loads from 101 CEDMs to the supporting columns of the cooling shroud and then to the seismic restraints that are connected to the refueling walls on both sides of the IHA (Figure 2). The CEDM seismic support is fabricated using carbon steel plates.

X Cable Bridge

Cable bridges are provided to support the cables between the refueling disconnect panels on the IHA and the containment cable trays mounted on the primary shield walls. The cable bridge is attached to the primary shield wall and is capable of being moved away from the IHA prior to the removal of the IHA from the reactor vessel (Figure 3).

IHA DESIGN ASPECTS

The structural design of the IHA has been performed to maintain the integrity under the loads of dead weight, lifting load and the safe shutdown earthquake. The design of each component is described below.

Cooling Shroud Assembly Design

The Cooling Shroud Assembly in the IHA consists of bottom ring plates; supporting columns; cooling shroud plate; CEDM plenum plate; cooling baffle; and ring beam angles.

A 3-in thick 9-in wide bottom ring plate is provided over the RPV head pads all around. The bottom ring plate is bolted to the RPV head pad by 1-in diameter A325 bolts (one bolt per pad). The bottom ring plate is also bolted to the RPV head lift lug pad. The supporting columns are connected to the bottom ring plate with 1-in diameter A325 bolts.

Supporting Column Assemblies are made of 6 - W6 x 20 structural columns to support the shroud and to take the horizontal loads. In addition, horizontal bracing at increments of 112.2" from the bottom of the bottom ring plate is provided along the column height to accommodate column heights of approximately 334". The supporting columns (W6 x 20) take the deadweight from all the components located below the missile shield, excluding the

reactor vessel head, the CEDM's, the bottom ring plate, and the lift rods.

16(c), 21, 22 A 1/4-in thick shroud plate is provided around the main and supporting columns. The shroud plate is designed as an enclosure and to take minimum loads. It is not, in general, designed to transfer loads from the reactor vessel head or from the CEDMs to the refueling pool wall. In the local regions of the shroud plate, however, it may be required to transfer loads from the CEDM seismic supports to the seismic restraints connected to the supporting columns. Wherever the access to the CEDMs and HJTCs are required, the access doors are provided on the shroud plate in the lower region of the shroud.

A 2-in thick plenum plate is provided under the CEDM shrouds and inside the IHA shroud. The plenum plate is provided with 101 9.5-in diameter holes for the CEDMs and two 8 in diameter holes for the HJTCs, 3 holes for main columns, the holes for supporting columns, and the holes for RCGYS piping.

The function of the cooling baffle is to separate the incoming flow area (where the CEDM cooling air flows downward along the lengths of the CEDM housings) from the outgoing flow area (where the air flows upward into the upper air plenum). Inside the IHA cl. 17 the baffle runs from the top of the CEDM plenum plate to the bottom of the missile shield plate. However, the baffle does not rest on the CEDM plenum plate. The baffle is designed to divide into several sections. These sections of the cooling baffles are connected to each other without using any gaskets at the interface.

Lifting Frame Design

16(21) A 5-in diameter solid rod with 4 UN threads on both ends of the rod is used for the lift rod in the main column assembly. A 3.5-in diameter solid rod is used for the lift rod clevis pin. A 5.5-in diameter rod threaded on both ends is provided for each leg of the tripod assembly. A 3.5-in diameter rod is provided for the clevis pin at both ends of each tripod leg.

Cooling System Design

The cooling fans are powered through the power cables which are routed over the cable bridge. Connectors are provided on the RDPs for the fan cables so they can be disconnected in a similar manner as the CEDM and RSPT cables. Each fan will also be equipped with instrument lines that will be routed to the control room for the operator to manually switch the operation from one fan to the other. Generally, the fan operation is rotated between three fans on a regular basis by the control room operator to minimize wear on one fan more than the others. cl 23, 24, 25 The upper air plenum consists of the top plate provided in three removable sections; the supporting frame supporting the upper air plenum; and side plate making an enclosure for the upper air plenum which provides the inlet to the cooling fans.

Missile Shield Design

16(c) 26 A 2-in thick steel plate is provided for the missile shield. The missile shield supports the upper air plenum, cooling fans, and the lift tripod and its accessories. The missile shield is designed to take loads from the upper air plenum, the cooling fans and fan supports, the lifting tripod, and the access ladders.

Head Area Cable System Design

The IHA Head Area Cable System includes a messenger tray; four refueling disconnect panels; CEDM power cables; RSPT cables; HJTC cables; ALMS cables; LPMS cables; fan power cables; fan PDT cables; fan motor space heater power cables; and cable supports.

The messenger tray is located above the top of the CEDM housings. It provides permanent support and routing for the CEDM power cables, the RSPT type I and type II cables and other cables. Once these cables are laid out on the messenger tray they are

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normally not disturbed. There are at least two levels in the messenger tray which are used to layout the cables. Generally, the power cables and the instrumentation cables (RSPT type I and type II) are separated by a required distance along their lengths so there is no signal interference between the cables. Also, the power cables are larger in diameter when compared to the instrumentation cables and, therefore, the power cables require larger bend radii in the layout. The messenger tray consists of at least two-level supports connected to the circumferential ring beams, supporting columns or baffles of the shroud assembly.

The head area cables inside the IHA terminate at the RDPs. The RDP constitutes the interface with the mating cables on the cable bridge. The cables in the IHA are disconnected at the RDPs and the cables inside the IHA remain with the IHA all the time. The RDPs are plates on which the cable connectors are mounted. The cable connectors are arranged in an orderly fashion on the RDPs for the convenience of connecting and disconnecting during the outage. Four RDPs are provided in the IHA above the CEDM housing tops. Two RDPs are provided on the 0° side of the reactor and two RDPs are provided on the 180° side of the reactor. Each RDP has 7 columns and 13 rows of connector ports. Each RDP can provide 91 cable connections and the total number of available cable connections on four RDPs will be 364.

The KNGR has 101 CEDMs. Each mechanism has one power cable and two RSPT cables. Therefore, 303 CEDM cables need to be routed inside the IHA from the top of the CEDM housing to the RDPs. The individual cable lengths from each CEDM are calculated to insure an orderly arrangement in the messenger tray located above the top of the CEDM housing.

In the KNGR there are two HJTCs provided on the top of the reactor vessel closure head. One HJTC is located approximately at 125° and the other HJTC is located approximately at 305°. The routing of the HJTC cables starts at the top of the HJTC probes and terminates at the RDP. For maintenance purposes, the HJTCs are left outside the baffle and between the baffle plate and the shroud plate. Doors will be provided on the shroud to access the HJTCs.

The NIMS cables include three ALMS cables and three LPMS cables. These cables are routed inside the cooling shroud along the height of the main columns and terminated at the RDP.

The cooling fan power cables and heater cables are selected to meet the requirements of the cooling fan. The fan power cables and the fan heater cables are routed along the side of the missile shield and to the RDP below the missile shield. The cooling fan pressure differential transmitter (PDT) power cables are selected to meet the requirements of the cooling fan. The fan PDT power cables are routed along the side of the missile shield and to the RDP.

Cable Bridge Design

There are two cable bridges supported by the primary shield walls, on either side of the RPV and located 180° apart. The cables are arranged in such a way that there are seven layers of cables with each layer containing a maximum of 28 cables (Figure 4). The bridge is equipped with a sling at its outer end (the tip of the bridge) and a lifting mechanism which rotates the bridge along a horizontal axis in a hinge provided at the inner (the wall) end. In its lifted position, it makes a 5 degree angle to the vertical. The cable bridge will serve to disconnect and connect the cables from the IHA conveniently and swiftly during the refueling period.

DESIGN BENEFITS AND CONCLUSION

A design of an Integrated Head Assembly is performed for the 1450 MWe Korean Next

Generation Reactor. It meets the cooling requirements for the CEDM by providing sufficient air flow with three cooling fans. The design of the IHA also provides a reliable lifting frame to lift the IHA with the RV closure head in a single lift.

With the IHA, the refueling outage duration will be reduced by 4 to 5 days due to a single lift of the RV head area equipment as they would otherwise be required to be lifted separately. Utilization of the IHA will delete the operation of disconnecting the CEDM and RSPT cables at both ends. The cables will be disconnected only at the RDP side. The IHA will eliminate the polar crane demands during the critical path of the refueling outage. This leaves the polar crane available for other activities, thereby greatly increasing the flexibility in the sequencing of outage activities. Laydown space in the containment building that would otherwise be needed for CEDM cooling manifold, ductworks, and Head Area Cable Tray will be allowed for other equipment. It is expected that the IHA concept will contribute to the reduction in radiation exposure by 90 % to the head area handling operators. The IHA will eliminate risks to personnel safety involved in the activities of disassembly and re-assembly of the CEDM manifolds and ductworks.

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